NERRS Science Collaborative Progress Report for Period 03/01/2011 through 08/31/2011

Project Title: Nitrogen Sources and Transport Pathways: Science and Management Collaboration to Reduce Nitrogen Loads in the Great Bay Estuarine Ecosystem

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*Figures displayed at end of document.
Figure 1: Nitrate concentration results at extensive stream sites from 2nd round spring 2011.
Figure 2: Total dissolved nitrogen (TDN) concentration results at extensive stream sites from 2nd round spring 2011.
Figure 3: Preliminary nitrate isotope ($\delta^{15}N$ and $\delta^{18}O$) results from select intensive sites.
Figure 4: Preliminary stream sediment isotope results from select intensive sites.
Appendix A: Nitrogen Source Collaborative Advisory Board (NSCAB) List

<u>A. Progress overview</u>: Overall goal of project and brief summary of what we planned to accomplish during this period including progress on tasks for this reporting period:

The Great Bay (GB) National Estuarine Research Reserve (NERR) ecosystem has experienced a decline in ecosystem health over the last 25 years and increased nitrogen (N) concentrations in GB have contributed to habitat degradation. The impacts from excess N have been identified as a driver of reduced eelgrass coverage, decreased oyster populations, and periodic depletion of dissolved oxygen in the Bay. As a result, the GB has been listed as "impaired" (i.e., Federal Clean Water Act) by elevated N resulting from both point and non-point sources (NPS) in the watershed. The original proposal addressed the gaps in our basic understanding of NPS N sources and transport in GB tributaries, with specific objectives to: 1) map the nitrogen hot spots in surface waters within the watershed; 2) identify the sources of nitrogen that result in these hot spots; 3) characterize the flow paths that deliver N to these hot spots; 4) determine whether N removal occurs in vegetated riparian buffers with different land uses; 5) examine nitrogen attenuation potential in stream and river channels and 6) integrate the results of these scientific investigations and make them accessible and useful to environmental managers and stakeholders.

An integral part of this project has been to collaborate with stakeholders to refine or revise these objectives to meet stakeholder needs and concerns for policy-relevant science. During this 6 month reporting period, our plans were to continue work on original objectives 1 and 2 while incorporating stakeholder input (objective 6). The following tasks were scheduled: 1) Re-sample the extensive stream sites (approximately 250); 2) Process and analyze stream samples for N concentrations; 3) Select ~ 20-25 intensive study sites for N tracer work; 4) Develop multi-tracer methods which will be used to determine the source of non-point N at intensive sites; and 5) conduct stakeholder meetings and integrate feedback into our project objectives. Tasks 1 and 2 were completed. Significant progress on task 3 has been made and several intensive sites have been selected to represent end members (all forest, mostly agricultural, all septic, all sewered) and combinations of mixed land use. Intensive tracer work supported by this project will be complemented by recent collaboration with EPA. EPA will sample 16 sites in the GB watershed for pharmaceuticals and personal care products (PPCPs) analysis and we will use these data to help identify the potential for non-point sources such as leaky sewer lines or septic systems to contribute to observed N loads in our study streams. We have worked with EPA on site selection and will also apply our multi-tracer methods to these sites for further identification of non-point N sources. Progress on task 4 has involved laboratory testing of standards and samples from intensive sites to evaluate and refine analytical methods for isotopes, optical brighteners, caffeine and mitochondrial DNA (mtDNA). Progress on task 5 has been substantial and has resulted in a refinement of our original project objectives.

B. Working with Intended Users:

Progress on tasks related to the integration of intended users into the project for this reporting period.

1. **Science Symposium:** The Collaboration Team worked with the Southeast Watershed Alliance to plan and implement a science symposium in May, 2011 to address issues facing the Great Bay watershed, including nitrogen, bacterial contaminants, metal toxins, and turbidity, among other issues. The goal of the forum was to develop a science-based foundation to support management decisions and solutions in the Coastal Watershed by summarizing existing technical information relevant to water quality impairments in the coastal watershed, engaging panelists in dialogue as to whether or not existing information is adequate to support regulatory, management and remediation decision, and to identify gaps in the current knowledge. The SWA sponsored the forum, but the collaboration team helped develop the symposium, identify presenters and stakeholders, plan the symposium, and handled all registration. Michelle Daley presented the goals of this project as well as preliminary results, along with results of another project related to nitrogen in the estuary. The symposium enabled rich discussion of the nitrogen issue, in the context of broader issues facing the estuary. Participants included scientists, municipal officials, state representatives, regulatory agencies, consultants, private citizens, non-profits, and interest groups.

2. **Nitrogen Sources Collaborative Advisory Board (NSCAB):** Based on the recommendation from the NERRS Science Collaborative, thirteen stakeholders representing diverse interests were invited to participate on a Nitrogen Sources Collaborative Advisory Board (NSCAB) to guide the process: everything from providing input on the objectives and guiding the implementation to helping to frame products that will be of use and benefit to watershed decision-makers. The Board meets quarterly and the first meeting was held on June 14, 2011 where we:

- Conveyed the project purpose and objectives
- Provided an overview of the science and how it pertains to individual local managers
- Members provided input on the objectives and outcomes
- Members discussed what they would like to get out of the project and how they would like to be engaged
- Discussed the need for a line of communication to keep them (and other stakeholders) engaged and appraised of the project

The NSCAB wanted to meet more often (quarterly) than requested by the project team (twice a year) and this was incorporated into the NSCAB process. A second meeting will be held in early fall. For current list of members see Appendix A.

3. **E-Newsletter:** Based on the expressed need for communication by the NSCAB members present at the June meeting, the science team and collaboration team is working on developing an e-newsletter to keep NSCAB members and other watershed stakeholders engaged in the project. The team is in the process of designing the first e-newsletter (using Constant Contact). The newsletter will provide an overview of the issues facing Great Bay watershed (with focus on nitrogen), provide a brief overview of the project (with link to NOAA/NERRS project website), depict preliminary findings with links to more info on the NH WRRC website, invite guest articles to be written from different perspectives, and incorporate a survey that queries NSCAB, stakeholders, and community decision-makers what science-based products they would like to get out of this project and in what form.
4. **Dover Study:** In collaboration with a Masters of Development class, taught by Dr. Joel Hartter and Dr. Charlie French, students conducted an assessment of public attitudes and awareness of issues facing Great Bay, particularly around nitrogen. Six municipal officials, four conservation groups, two economic development practitioners, a city engineer, and 40 residents of the community were interviewed or completed a survey. The data were compiled in a report outlining public perceptions. The report also lays out policy options to address the broader issue of protecting water quality in Great Bay (without judging the merits of each).
5. **Digital Media Website:** Dialogue has been initiated with John Forcucci, VP of Digital Media at New Hampshire Public Radio, to incorporate information, findings, and discussion about this project on NHPR's Great Bay digital media site. The site will enable the public to engage in discussion around the issue and query the science team in a controlled manner. John is hoping to develop content and link to resources and data from the project in early 2012.
6. **Science to Decision-making Assessment:** A Tides Fellow, Colin Lentz, is developing an assessment of how science can best inform local and regional decision-making and policy around issues facing Great Bay. This assessment will identify what types of products decision-makers would like to have from collaborative science (e.g. data, testimony, decision-support, etc.).

What we have learned as well as unanticipated challenges or opportunities.
From our recent presentation at the Great Bay's Hugh Gregg Coastal Conservation Center, we have learned that it is imperative that we work to engage a more diverse group of intended users in targeted (smaller) venues. This allows for comfortable exchange of information and viewpoints without alienating valuable stakeholders.

Since the complexity of nitrogen chemistry may be difficult for decision-makers to digest, we need to develop educational outreach materials that outline the big picture. We understand that it is essential to convey scientific information and outcomes to the public that emphasize implications for communities and the watershed as a whole. Our approach from the 1st six months has evolved to include more targeted meetings and communication to those interested (and sometimes not as interested) groups (see section D). We continue to respond to participants from stakeholder meetings who have stated that our research team needs to make information about nitrogen issues, and the project in general, more accessible to both community decision-makers as well as the public-at-large. In an effort to respond to this need, we are developing a newsletter with on-going data available.

When writing this grant we had presumed the Southeast Watershed Alliance (SWA) —a regional organization that was established through state legislation to plan and develop implementation measures to improve and protect water quality in the Great Bay watershed to meet clean water standards— would be the best conduit to decision-makers, but we realize now this is not necessarily the case. The organization consists of multiple stakeholder interests and needs more time to mature as an organization. As a result, Science Collaborative suggested that we develop an advisory committee to guide the process and we have developed the NSCAB (Section B 2).

Partners Involved

The project partners have remained largely the same, with the inclusion of two new partners, the NSCAB and UNH's Masters in Development Policy and Practice Program (MADPP). The SWA, which was originally to serve an advisory role for the project, will no longer play a direct advisory role. The NSCAB, which is a smaller, but representative group of stakeholder interests, will take on that role. Project partners include:

1. Piscataqua Region Estuaries Partnership (PREP)
2. University scientists focusing on the Great Bay watershed
3. Southeast Watershed Alliance
4. Great Bay National Estuaries Research Reserve
5. UNH Cooperative Extension
6. NH Water Resources Research Center
7. NH Department of Environmental Services/ Piscataqua Region Estuaries Partnership (via Phil Trowbridge)
8. Lamprey River Watershed Association (Dawn Genes)
9. Training for the Integration of Decision-Making and Ecosystem Science (TIDES) Program
10. Nitrogen Sources Collaborative Advisory Board (NSCAB). See Appendix A
11. Masters in Development Policy and Practice Program, UNH (Dr. Joel Hartter)
12. U.S. Environmental Protection Agency (EPA), Region 1

Interactions with intended users have brought about some changes to our scientific approach, including integration of intended users and project objectives.

We continue to encourage discussions with new and existing people and organizations that have become engaged and interested in this project. An example of how continued feedback and interaction has shaped our project was at our presentation in Newington, NH on July 14, 2011. During discussion at this meeting, a participant suggested that an additional site in Newington which receives significant runoff from impervious surfaces be added to our extensive sampling effort. This person had valuable local knowledge about the town and knew that the runoff patterns in the area of interest were actually different than GIS predictions. As a result, we have added this site to our extensive network. Discussions evoked by this presentation were positive and thoughtful. Another participant followed up with the thoughtful comment: “I enjoyed your presentation in Newington last week. UNH is doing some very useful work with respect to the Great Bay watershed. One area that peaks my curiosity is the impacts of the wetlands. You made the point that the dissolved organic nitrogen (DON) appears to be related to natural causes as opposed to man-made causes. I wonder if this area that warrants more research moving forward in your studies.” This participant was referring to background data on the Lamprey and Oyster watershed and in response to comments such as this one we have modified and expanded our scope for Objective 1 (see section C for full description) to include an assessment of how DON relates to natural and anthropogenic landscape features among the ~250 extensive sites throughout the entire GB watershed.

How we anticipate working with intended users in the next six months.

We will continue to reach out to our intended user groups as we have in the previous 6 months (see above in section B). In the next six month phase, specific activities include:

- Distribute the project newsletter and implement survey of end-user needs (September/October)
- Hold second NSCAB meeting (September/October) and set up NSCAB meeting schedule for 2012
- Incorporate NSCAB input and engage NSCAB in continued dialog through newsletter, website, individual communications and meetings.
- Continue to engage a more diverse group of intended users in targeted (smaller) venues. The next meeting of this type is scheduled in Newmarket on September 26, 2011 and members of the Town Council, Conservation Commission and the general public are invited to attend.
- Add preliminary data to the WRRC website that is linked to the newsletter. This will enable us to target and communicate effectively what is rolled out.
- Complete the science-to-decision-making assessment to show how science can best inform local and regional decision-making and policy around issues facing Great Bay. Findings to be shared at public meetings.
- Develop a plan to disseminate project info on NHPR's digital media website. The site will invite input (moderated by NHPR) that will be useful in framing how best to package the project findings for public consumption, particularly use by key decision-makers.
- Engage the SWA and other stakeholders when and where an appropriate opportunity is available such as at the NHDES Water and Watershed Conference in March 2012.

C. Progress on project objectives for this reporting period:

Changes to methods, the integration of intended users, and the intended users involved or the project objectives

Objective 1: Identify and map the nitrogen hot spots in surface waters within the Great Bay watershed – Extensive sites

Several stakeholders, including members of the NSCAB and participants attending the January 2011 Lamprey Science Symposium and discussions in section D, have asked if this project will give towns their nitrogen budget and determine how much nitrogen each town is contributing to Great Bay. Because watersheds do not follow town boundaries, it is difficult to meet this request. However, we have significantly expanded the scope of Objective 1 to develop products that will be useful on a town by town basis.

In the original proposal, we were only planning to sample our 250 extensive sites once and use the results to select sites for intensive tracer work. Since there is significant interest in generating maps of estimated or measured nitrogen concentration on a town and even neighborhood basis, we plan to sample the ~250 extensive sites multiple times and develop spatial models using this data coupled with a GIS. Specifically we will do the following tasks:

1. Complete four synoptic sampling events of the ~250 extensive sites and analyze data. Remaining synoptic events are scheduled for baseflow conditions in Sept and the spring flush in 2011. This will be completed in year 2.
2. Determine human population density (separating septic and sewered), impervious surface cover and land use for catchments draining to the ~250 extensive sites and the ~3500 catchments throughout the entire Great Bay watershed identified by the NH Geological Survey (NHGS) using 10 meter DEM data. This GIS analysis will be done in conjunction with NH DES and the NHGS. This will be completed for the ~250 extensive sites in year 2. The GIS analysis for the ~3500 NHGS catchments will begin in year 2, but may carry over into year 3.
3. Determine if the existing DIN vs. population density model developed mainly on Lamprey basins can be accurately applied to the ~250 extensive sites throughout the Great Bay watershed. This will be completed in year 2.
4. Use these ~250 extensive site data to build and calibrate a spatial model for the entire Great Bay watershed that best predicts N concentration based on landscape characteristics (human population density, impervious surface cover and land use). We will refer to this as the Great Bay landscape model. This will begin in the second half of year 2, but may carry over into year 3.
5. Apply the new Great Bay landscape model to the ~3500 NHGS catchments throughout the Great Bay watershed. This will begin in the second half of year 2, but may carry over into year 3.
6. Identify stream “hot spots” throughout the entire Great Bay watershed using the following two different approaches. This will be completed in the first half of year 3.
   I. Compare predicted or measured N concentrations to the benchmark nitrogen criteria established for Great Bay (0.30 mg N/L to protect eelgrass and 0.45 mg N/L to protect DO levels). Each of the ~3500 NHGS catchments can be

categorized as meeting or failing criteria to support eelgrass and or DO levels in Great Bay. "Does your stream reach contribute to the problem in Great Bay" can then be easily assessed by residents of each of the ~3500 NHGS catchments.

II. In addition to just identifying "hot spot" areas where N is high, we will also look for "outliers" among extensive sites (i.e. those with large residuals) from the Great Bay landscape model.
    - If we can identify catchments that have disproportionately high N in comparison to other catchments with similar landscape characteristics, those outlier catchments can be targeted for N reduction
    - "Outlier" sites that have disproportionately low N in comparison to other catchments with similar landscape characteristics can serve as examples of good watershed management

7. NH DES is developing a Nitrogen Loading Model (NLM) for the HUC 12 watersheds in the Great Bay watershed (~40). This NLM will be developed mainly using nitrogen inputs and attenuation rates from published literature and reports along with GIS analysis of the HUC 12 watersheds. Our Great Bay landscape model will enhance the NH DES NLM in the ways identified below. The timeline of this task is contingent on the development of the NLM, but we anticipate completing this task early in year 3.

    I. We can evaluate the accuracy of the NLM by comparing NLM predicted concentrations at the HUC 12 watersheds to measured N concentrations at our extensive sites or modeled N concentrations from the new Great Bay landscape model which will be specifically calibrated to the Great Bay watershed.

    II. Our Great Bay landscape will provide towns with information on nitrogen in their town at a smaller scale than the NH DES NLM and can be used to facilitate targeted nitrogen reduction.

Objective 2: identify the sources of nitrogen that result in hot spots - Intensive sites

Intensive tracer work has been expanded to include more sites (20-25 instead of the 10 originally proposed) and an additional tracer method. We recognize that with the complexity of identifying non-point sources in mixed land use and stakeholder requests for this project to provide guidance on the relative contribution of nitrogen from stormwater runoff compared to septic systems, we must expand this objective to include intensive study sites that represent end members (all forest, mostly agriculture, all septic, all sewered, golf courses etc.) and combinations of mixed land use. Limiting our scope to 10 intensive sites would not be enough to properly test and apply our multi-tracer methods.

Additionally, stakeholders are interested in the contribution of N from pet waste in urban/suburban areas and the contribution from manure in agricultural areas. Therefore, instead of developing a boron isotope technique that is redundant with our optical brightener method for identifying domestic wastewater (i.e., laundry detergent), we will develop a microbial source tracking method. Mitochondrial DNA analysis allows for the identification of the specific animal source (e.g. human, dog or cow) and enhances the isotopic nitrogen analysis which can categorize the source as animal waste, but cannot detect the type of animal waste.

Intensive tracer work supported by this project will be also be complemented by recent collaborative efforts with EPA. EPA will support PPCP analysis at a subset of our intensive sites.

When a member of the NSCAB asked if we would be able to use pharmaceuticals as part of our tracer work, we were happy to report that we would because of this collaboration with EPA.

Objectives 3: Identify N delivery pathways at intensive study sites

No substantial changes have been made.

Objectives 4: Examine extent of riparian denitrification at intensive study sites.

No substantial changes have been made in our overall approach and objectives but measurements will be limited to collecting and analyzing samples from two groundwater wells (one upslope and one downslope) in a subset of our intensive sites.

Objective 5: Examine in-stream nitrate attenuation

This objective has been significantly modified to allow for expanded effort on objective 1 and for the development of more user-friendly products and increased collaborative efforts with stakeholders. The entire field component of measuring nitrate uptake has been removed. Work on this objective will be limited to determining nitrogen uptake in large river reaches using mass balance of predictions from the Great Bay landscape model. Work on this objective will begin in year 3 after GIS landscape models are developed from expanded efforts on Objective 1.

Objective 6: Integration of science with end users

Plans for integration of end users are discussed in more detail in section B. Maps of nitrogen "hot spots" generated from field data and the new Great Bay landscape model in Objective 1 will be useful tools to work with towns and discuss options for reducing hot spot contamination in their specific town or in a specific neighborhood. The significant reduction of efforts on Objectives 4 and 5 will allow us to re-allocate resources for expanded efforts on objective 1 and will also allow for more time to be spent on integration and collaboration efforts.

Progress on tasks related to project objectives and data collected

Objective 1: Identify and map the nitrogen hot spots in surface waters within the Great Bay watershed – Extensive sites

Tasks to meet objective: 1) Additional sampling of extensive study sites at seasonal time periods across length of study, 2) laboratory processing and quality control analyses of all water samples, and 4) compile data and develop a map of N "hot spots."

Progress on tasks

We have completed a 2nd round of "synoptic" sampling of the ~250 extensive sites during May 2011. Samples have been analyzed for dissolved nitrogen species ((NO_3^-, NH_4^+ and dissolved organic nitrogen (DON)). Preliminary results show that sites have a range of nitrate and TDN concentrations and some are potential N "hotspots" (Fig. 1 and 2). Additional synoptic sampling will serve to better characterize the average N concentration at these sites.

Objective 2: identify the sources of nitrogen that result in these hot spots - Intensive sites

Tasks to meet objective: 1) Complete selection of intensive study sites that represent end members (all forest, mostly agricultural, all septic, all sewered) and combinations of mixed land use 2) continue method development and testing NPS N multi-tracers (isotopes, optical brighteners, caffeine and mtDNA) 3) continue surface water and sediment sampling for nitrogen analysis and multi-tracer testing and application 4) and establish shallow groundwater wells at intensive sites.

Progress on tasks

The intensive site selection process is nearly complete. We have selected over 20 stream sites where we will use multi-tracers to identify the major NPS of nitrogen. To accomplish this, we must first test our tracer methods on sites with uniform land use (end members) and on samples from known sources (parking lot runoff, wet deposition, sewage effluent etc.). As part of a new on-going collaborative effort with the EPA, 16 of our intensive sites will also be analyzed for PPCPs. Significant progress has been made on method development and testing NPS N multi-tracers (isotopes, optical brighteners, caffeine and mtDNA). Progress made on each method is described in more detail below. These tracer methods are essential to identify the NPS that produce individual N hotspots and to utilize in N delivery pathway delineation. Upslope and downslope shallow groundwater wells were established at 2 intensive sites. Other designated intensive sites with mixed land use will be instrumented with shallow wells over the next 6 months. Data collected and analyzed on preliminary tracer testing has begun during this six month period.

Method Development and Tracer Testing

Nitrate stable isotopes – The isotopic signature of nitrate is useful in differentiating between the following categories of non-point N sources: fertilizer, animal waste, and atmospheric deposition. Through a collaboration with Dr. Meredith Hastings of Brown University, we are utilizing a bacterial denitrification technique coupled with a dual isotopic method ($\delta^{15}N$ and $\delta^{18}O$) to measure nitrate in stream, ground and rainwater samples. We completed testing water samples for nitrate isotopes for a subset of the intensive study sites. The $\delta^{15}N$ and $\delta^{18}O$ nitrate data showed that the stream and groundwater samples reflected the isotopic signature of animal waste, but not wet deposition, stormwater runoff or fertilizers (Fig. 3). For example, the isotope values of nitrate originating from the exchange with precipitation have higher $\delta^{18}O$ values because of fractionation effects that occur between the atmospheric H_2O (Kelly and Ray 1999, Kendall et al. 2000). The $\delta^{15}N$ of wet deposition sample fell within the range of atmospheric nitrate since it was greater in $\delta^{18}O$ values and above 20‰. The well samples from the agricultural farm were within a predicted value range (10-20‰) for manure and animal waste. Interestingly, the BD5 sample was much higher in $\delta^{15}N$ and may indicate denitrification occurring in a ground water well that receives agriculture runoff.

Sediment $\delta^{15}N$ organics and nitrate concentration – We have results of stable nitrogen isotopes sampled from stream sediment results from a subset of intensive sites. Since the natural abundance of stable nitrogen isotopes can integrate ambient nitrogen exposure over time, it is meaningful to test whether a relationship exists between organic sediment and stream water nitrate. Measurements of $\delta^{15}N_{SED}$ (surficial stream sediment) were analyzed at the UNH, Stable Isotope Laboratory under the direction of Dr. Erik Hobbie showed a positive relationship with nitrate concentrations among the select sites. Preliminary results show that greater sediment $\delta^{15}N$ values were positively associated with higher nitrate (Fig. 4). Because $\delta^{15}N$ can be enriched in animal waste, a correlation between elevated nitrate and high $\delta^{15}N$ values may be indicative of nitrogen inputs from animal waste.

Caffeine – Caffeine is commonly found in human excrement and can be indicative of septic system effluent, leaky sewer lines or illicit discharges. The presence of caffeine coupled with elevated N suggests that human waste is a significant non-point source of N. We are testing our method to identify the presence of trace caffeine compounds in surface water and shallow groundwater samples using high pressure liquid chromatography (HPLC) and fluorescence spectroscopy.

Optical brighteners – We are also in the method development phase of detecting the presence of optical brightener compounds in water samples. This method will help identifying domestic wastewater contribution by detecting optical brighteners which are commonly found in laundry detergents.

Microbial Source Tracing –mtDNA
Mitigating the effects of N pollution associated with animal waste contamination in surface waters requires identification of the animal source. Fecal contamination is traditionally detected using microbial indicator organisms such as coliforms, *Escherichia coli* and *Enterococcus* spp. Further analysis is required to identify the type of animal that is contributing to the fecal contamination and analyzing host-specific microorganisms such as in mtDNA is an advanced method of microbial source tracking (MST).

We are developing this mtDNA MST method as an additional NPS N tracer technique which was not included in the original proposal in response to input from intended users. Local groups have expressed an interest in attempting to identify the extent to which animal waste from humans, cows or dogs contributes to NPS nitrogen inputs to the Great Bay. Mitochondrial DNA in conjunction with PCR or real-time PCR is used extensively in the fields of phylogenetics, forensics, and medicine. We are using similar methods from Caldwell et al. 2007 (*mtDNA Multiplex Real-Time PCR as a Source Tracking Method in Fecal-Contaminated Effluents*) to track human, dog, and cow waste contamination in river and streams in the Great Bay watershed. The goal is to be able to detect the origin of N particularly in mixed urban areas

Objectives 3: Identify N delivery pathways at intensive study sites

Tasks to meet objective: 1) collect samples from stormwater runoff (collected from road culverts or swales emptying directly into our intensive study streams), shallow groundwater and stream water at designated intensive study sites 2) analyze samples for nitrogen concentrations and use the multi-tracer methods to determine if the different sources of nitrogen are delivered via groundwater or stormwater runoff.

Progress on tasks
The majority of the progress associated with this objective is the method development for the multi-tracers. In the next six to 15 months, we will collect samples from established intensive sites to investigate the delivery pathways of N using our multi-tracer techniques.

Objectives 4: Examine extent of riparian denitrification at intensive study sites.

Stream water and two wells (upslope and downslope) at designated intensive sites will be sampled to quantify riparian groundwater N removal by examining changes in N concentration along the presumed flowpath and using nitrate isotope analysis to indicate if significant denitrification is occurring. Progress on this objective will occur mainly year 2, but we have begun sampling at two of the intensive sites.

Objective 5: Examine in-stream nitrate attenuation

This objective has been significantly modified and the field component of measuring nitrate uptake has been removed to allow for the development of more user-friendly products and increased collaboration efforts with stakeholders (see above). Work on this objective will begin after GIS landscape models are developed from expanded efforts on Objective 1.

Objective 6: Integration of science with end users

Progress: The various integration activities as described throughout this report continue to benefit the project direction and goals.

Unanticipated challenges, opportunities, and/or lessons learned.

Although we have made progress in translating the complex science issues related to nitrogen impairment in the Great Bay Estuary into a language that the stakeholders can understand, we continue to strive to improve the science translation. We have presented our project goals and preliminary results at local meetings and workshops and we have found that discussions with small groups can be very informative to both the stakeholders and to the scientists on this project. Our science translation has improved as we talk more with stakeholders about the project and we realize the need to simplify our dialog as much as possible. Recent feedback from our discussions with Newington was as follows: "Your presentation was very well received. The feedback I've received has been uniformly positive. Your knowledge of the subject matter and your easy going manner allowed you to connect well with the audience."

Plans for meeting project objectives during the next six months.

During the next six months, we will conduct a 3rd synoptic sampling of the ~250 extensive sites and continue to work on tasks associated with the expanded objective 1. Significant effort will be placed on tracer testing and tracer application to identify non-point sources of N at our intensive sites (objective 2).

We will also make progress on Objectives 3 and 4. We will be using the multi-tracer methods to understand N delivery pathways at intensive sites. As part of our continued outreach and collaboration efforts, we plan to use this data to help inform intended users where nitrogen is coming from and how delivered (i.e., atmospheric sources, fertilizer application, septic systems, or other sources?). Is it delivered via storm runoff or groundwater? Therefore, a wide variety of sources could be responsible for producing nitrogen hot spots.

Progress on Objective 5 will be deferred until after the expanded objective 1 is completed. Objective 6 and ongoing communication with the NSCAB will be maintained as data is collected and products are generated. Our collaborative science team continues to make progress on integration efforts to initiate and host workshops with the community. We will work through conflict resolution processes that will be useful during the course of this project.

D. Benefits to NERRS and NOAA: List of project-related products, accomplishments, or discoveries that may be of interest to scientists or managers working on similar issues that may be of interest to our peers in the NERRS, or to NOAA.

Meetings and workshops where project goals and objectives were presented and discussed

- Daley, M.L., McDowell, W.H. and Bucci, J. 2011. Nitrogen inputs, outputs, retention and concentrations in watersheds of the Great Bay Estuary system. NH Water and Watershed Conference. Plymouth, NH. March 2011.
- Daley, M.L. and McDowell, W.H. 2011. Nitrogen Research in the Lamprey River Watershed and the Great Bay Estuarine Ecosystem. Southeast Watershed Alliance Science Symposium. Portsmouth, NH. May 11, 2011.
- Daley, M.L., Bucci, J., McDowell, W.H., Hobbie, E., French, C., Potter, J.D. and Miller, S. 2011. Previous nitrogen research in the Lamprey watershed and current research in the Great Bay watershed. Nitrogen Sciences Collaborative Advisory Board (NSCAB). Hugh Gregg Coastal Conservation Center, Greenland, NH. June 14, 2011.
- Daley, M.L. and McDowell, W.H. 2011. Previous nitrogen research in the Lamprey watershed and current research in the Great Bay watershed. University of New Hampshire Balancing Resource Management, Land Use and Development class. Durham, NH. June 23, 2011.
- Daley, M.L. and McDowell, W.H. 2011. Identifying non-point nitrogen sources in the Great Bay watershed and moving towards sustainability. Sustainability on a Shoestring. Joint NH Department of Environmental Services and US Environmental Protection Agency Meeting. Concord, NH. June 24, 2011.
- Daley, M.L. and McDowell, W.H. 2011. Viewing Great Bay from a nitrogen (and watershed) perspective. Bay Views Presentation. Hugh Gregg Coastal Conservation Center, Greenland, NH. July 13, 2011.
- Daley, M.L. and McDowell, W.H. 2011. Non-point sources of nitrogen in the Lamprey and Great Bay watershed. Special Newington meeting including the Conservation Commission, Selectmen, Planning Board, Sewer Commission and interested residents. Newington, NH. July 14, 2011.

- McDowell, W.H. and Daley, M.L. 2011. Nitrogen Research in the Lamprey River Watershed and the Great Bay Estuarine Ecosystem. US EPA Region 1 meeting. Boston, MA. May 6, 2011.
- Interview and Press release from NHPR: McDowell, W.H. and Daley, M.L. 2011. "Sewer Plants in Great Bay Face Tougher Clean Water Standards" by Amy Quinton NH Public Radio. http://www.nhpr.org/sewer-plants-great-bay-face-tougher-clean-water-standards May 20, 2011.

E. Activities, products, accomplishments, or obstacles not addressed in other sections of this report that may be important for the Science Collaborative to know.

The effects of nitrogen on the Great Bay watershed continues to be an important yet sensitive issue in New Hampshire with the EPA listing of Great Bay as impaired. Certain local groups are stepping up their efforts to work with our project members to address this issue in a balanced approach. However, there remain challenges in working with other organizations since there are conflicting positions maintained by the diverse stakeholders. We are hopeful that the adjustments made in response to intended user input will improve our project's utility to the end user.

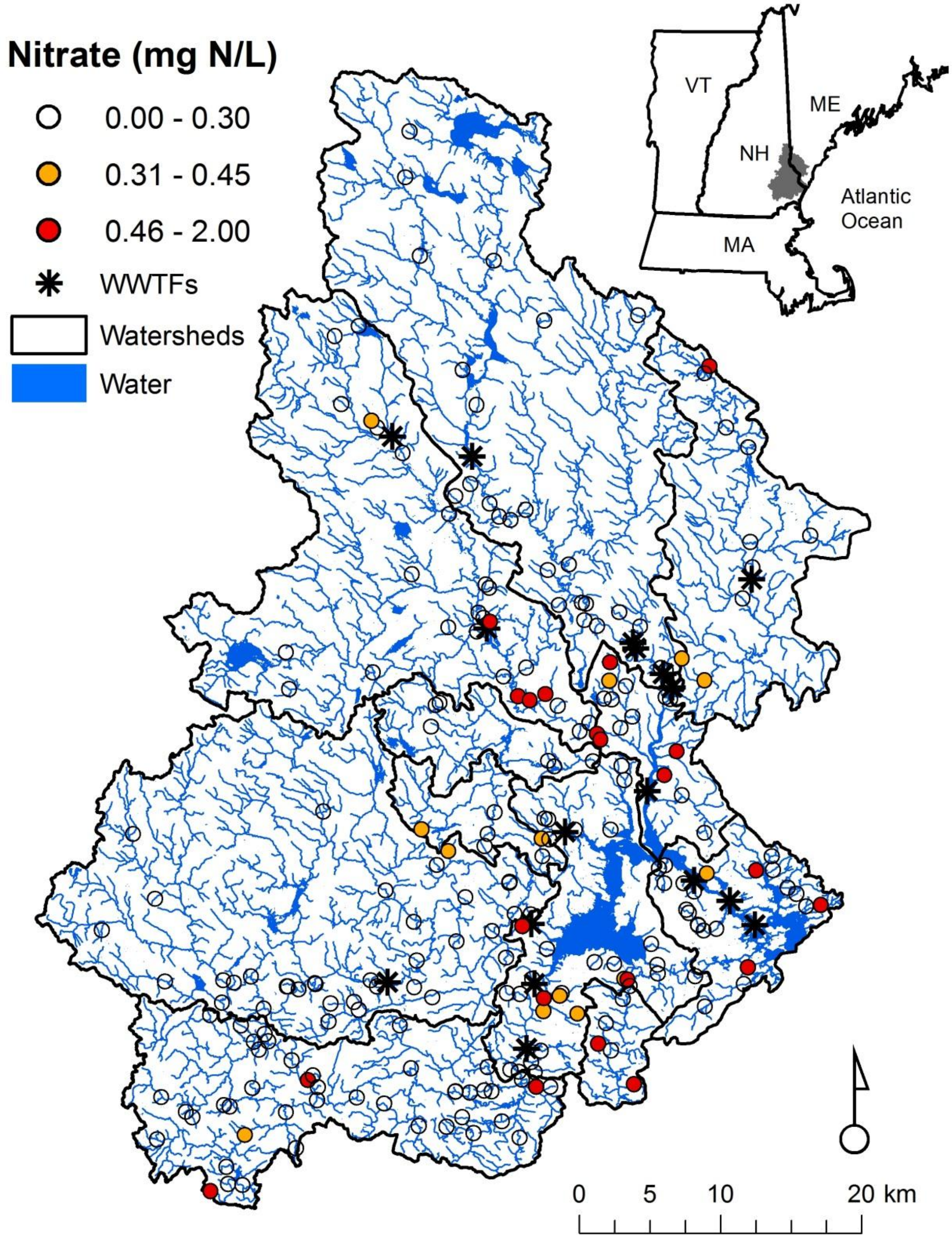

Figure 1: Nitrate concentration results at extensive stream sites from 2nd round, spring 2011.

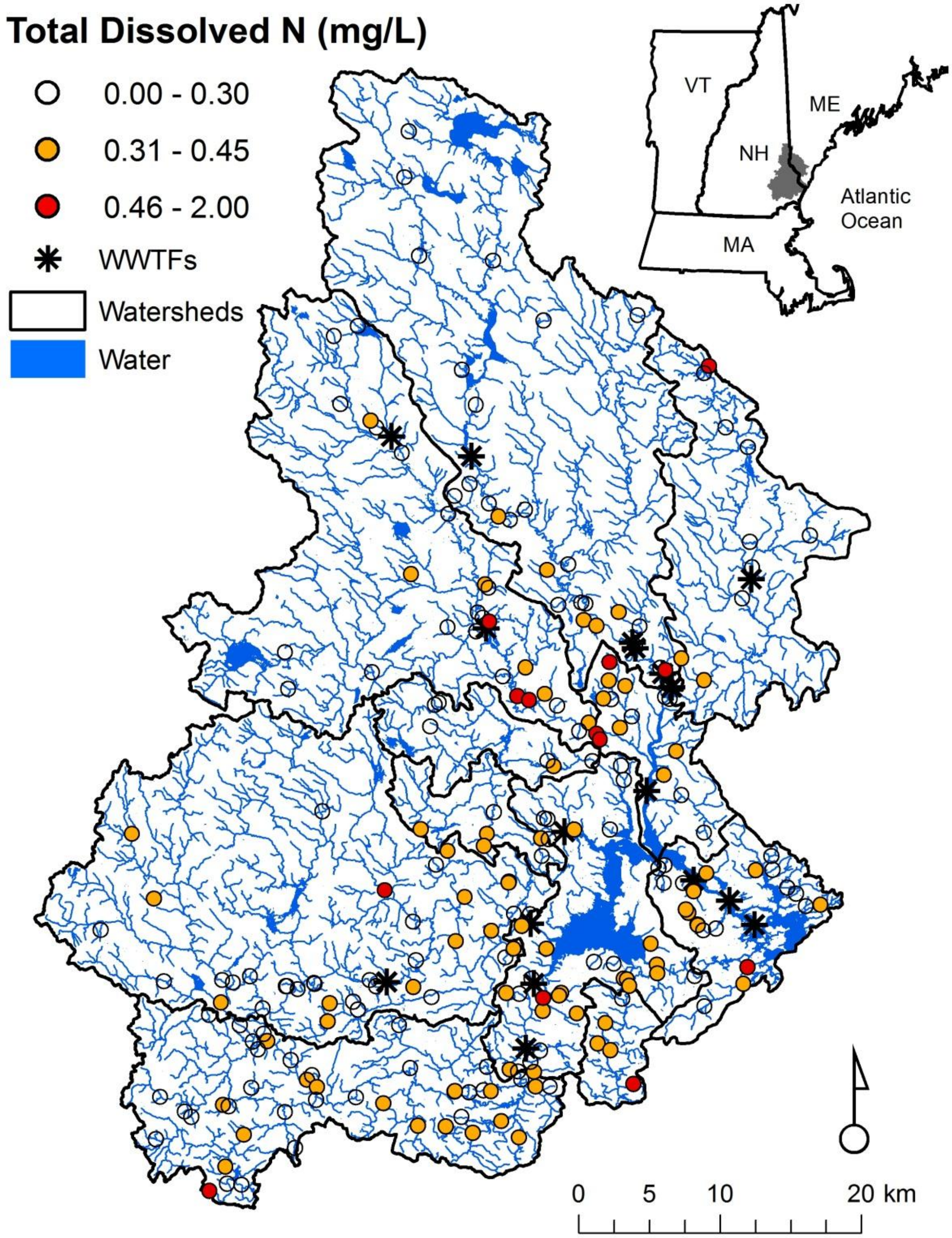

Figure 2: Total dissolved nitrogen (TDN) concentration results at extensive stream sites from 2nd round, spring 2011.

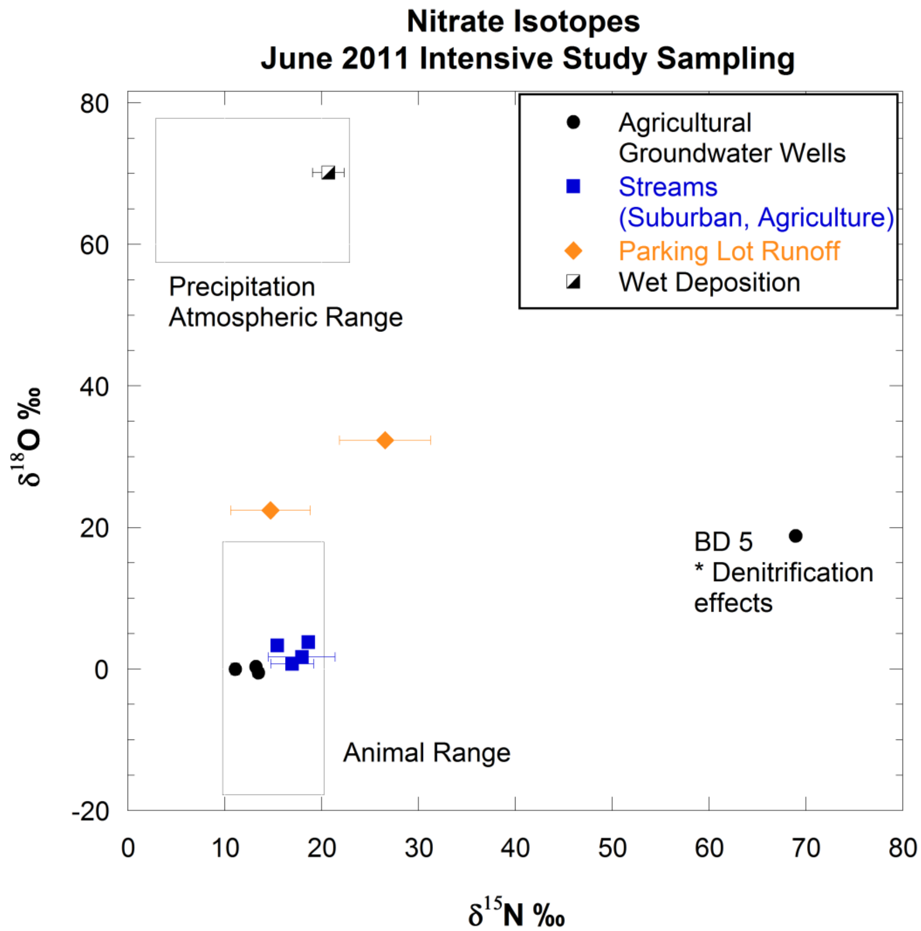

Figure 3: Nitrate isotope values from preliminary intensive sites.

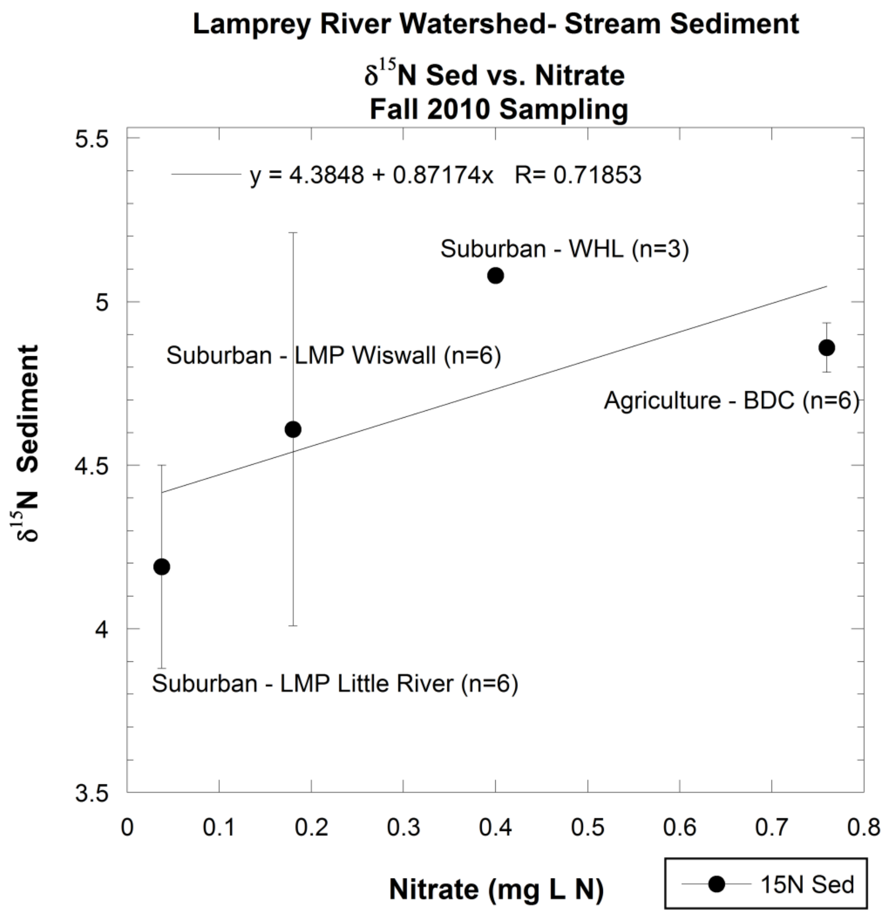

Figure 4: Nitrogen isotope values for stream sediment, which are compared to nitrate concentration from preliminary intensive test sites.

Appendix A: Nitrogen Sources Collaborative Advisory Board (NSCAB)

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